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A Study on STEAM Program Based on Measurement of Sugar Concentration in Korean Coffee Commercial Drinks Using Portable Refractometer (II)

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Abstract

In this study, we could be detected the content of sugar contained in the Korean coffee drinks by using three kinds of portable (including pen-typed) refractometers. The purpose of this work is investigated the reactivity of three kinds of refractometers to coffee drinks and to get a calibration curve from comparison with expected values and measured values.

From these results, we found that these refractometers were useful for measuring the sugar content in Korean coffee product and were useful for adopting as a STEAM material. And the expected values recalculated from TDS content has a good correlation with the measured values.

Keywords: Pen-typed refractometers, Sugar, Carbohydrate, TDS, STEAM Program

INTRODUCTION

In recent, beverage drinks became a wide range of products launched by a popularity and a variety of coffee shops have been arising in Korea. The positive effect and negative effect of coffee to a human body has been studied by many researchers [1-6]. In recent, the problem of child obesity and dental care due to increased tooth decay have been focused in one of the social issues [7-15]. So, a lot of research about the negative impact on the health of children has been published [16-21].

It is being said that school's teachers are responsible for the health of elementary school students in school. However, to measure the sugar content in the drinks and the concentration of sugar contained in the meals provided by the school, or in the markets around the school, it was requiring more time and expensive equipment [18, 19, 20].

However, in recent years, there is a portable refractometers development at domestic and abroad, is being released at an affordable price [22]. These refractometers have shown a lot of developmental functions like as an easy measure and a high reproducibility. Educational program development using such portable refractometers may be applied as part of the training STEAM epidemic in recent years [23, 24]. In particular, it is expected that students can also achieve pedagogical effect by confirming the sugar contained in the beverage directly of themselves.

In this study, using refractometers released in Japan, we tried to measure the sugar content of the coffee product in the country. In previous studies, we could be measured the sugar content in the coffee using three different types of refractometers [23].

In this study, we performed measuring the sugar content of the coffee product by using different refractometers. And then, we get a calibration curve from measured value by using refractometers and we confirmed the sugar content in the unknown coffee by using the calibration curve.

EXPERIMENT METHOD

Experiment Equipment

The refractometer utilized in this experiment are three types (including pen-type) as listed below. The brief features of each equipment are as follows [22].

PAL-S: The measurement range is Brix 0.0-93.0% and the resolution is Brix 0.1%. This equipment has measurement mode (Mode S) which prevents uneven measurement result in accordance with sample condition, which shows less errors that the previous method.

PEN-1st: As a pen-type, the measurement range is Brix 0.0-85.0%. The refractive index is Brix 0.1% and the accuracy is Brix+0.5%.

PEN-J: As a pen-type, the measurement range is Brix 0.0-85.0%. The resolution is Brix 0.1% and the accuracy is Brix+0.2%.

How to use the portable saccharimeters

1. Use micro pipette to collect 300 microliters from sample and drop on prism in the measurement equipment.
2. Push start button.
3. Read Brix value.
4. Repeat step 2 and 3 for 5 times.

How to Use the Pen-shaped saccharimeters

1. Put 75ml of sample in triangular flask (100ml) and stick the pen-shape equipment from top and fix it.
2. Push start button.
3. Read Brix value.
4. Repeat step 2 and step 3 for 5 times.

RESULT AND DISCUSSION

A. Experimental example

The ingredients and contents of sample A, the espresso cream coffee (drink type: dairy drink, volume: 240ml) used in this experiment were described in <Table 1>.

Table 1: Ingredients and contents indicated on label of sample

mL	Caffeine (mg)	carbohydrate (g)	Sugar (g)	Protein (g)	Fat (g)	Satu. fat (g)	Trans-fat (g)	Cholesterol (mg)	Salt (mg)
240	70	23	21	3.5	4.0	3.0	0.0	150	50

Measurement result

The expected values of sugar content in sample A were used by recalculating the total amount of sugar or carbohydrate or dissolved solid(TDS) by each standard(X-axis). The expected value of sugar content obtained by converting the sugar content labeled on surface of coffee products (can or bottle) was 8.8. And the expected value of sugar content obtained by converting the carbohydrate content labeled on surface of coffee products (can or bottle) was 9.6. And the expected value of sugar content obtained by converting the TDS content labeled on surface of coffee products (can or bottle) was 12.8.

The measured values obtained by using three portable refractometers in this experiment were provided in <Table 2>. <Table 2> showed that the measured values were all lower than the expected values for three refractometers (measurement value: 12.36~12.64). In case of PEN-J refractometer, it was shown 0.44 point lower than the expected value (12.8).

Table 2: Measured value of sugar content by using three different type of refractometers to sample A

	1st	2nd	3rd	4th	5th	Ave.
PAL-S	12.50	12.40	12.50	12.50	12.60	**12.50**
PEN_1st	12.50	12.60	12.70	12.70	12.70	**12.64**
PEN-J	12.40	12.30	12.40	12.40	12.30	**12.36**

Correlation coefficient of measured values

In <Table 3>, the correlation of the values measured by three different kind of refractometer could be evaluated using statistics program with SPSS 18. According to the statistics analysis, there was a significant result among the measurement devices. Even if there were slight differences between three measured values, but they shared a mutual dependability. Therefore, this result verified the credibility in measuring sugar content by any of three refractometer tools used in this study [23].

Table 3: Correlation between measured values by three different type of refractometers (A: PAL-S refractometer, B: PEN-1st refractometer, C: PEN-J refractometer)

		A	B	C
A	Pearson correlation coefficient	1	.984**	.991**
	probability		.000	.000
	N	46	46	46
B	Pearson correlation coefficient	.984**	1	.996**
	probability	.000		.000
	N	46	46	46
C	Pearson correlation coefficient	.991**	.996**	1
	probability	.000	.000	
	N	46	46	46

Table 4: Expected value of sugar content by considering the concentration of carbohydrate, sugar, and TDS labeled in total samples (A: expected value of sugar content from carbohydrate, B: expected value of sugar content from sugars, C: expected value of sugar content from total dissolved solids)

	mL	Carbohydrate	A	Sugars	B	Protein	Fat	C
Coffee1	200	25	12.5	23	11.5	3.0	0.6	14.3
Coffee2	200	20	10.0	20	10.0	3.8	2.4	13.2
Coffee3	240	23	9.6	21	8.8	3.5	4.0	12.8
Coffee4	240	23	9.6	21	8.8	3.5	4.0	12.8
Coffee5	240	24	10.0	20	8.3	2.0	1.9	11.7
Coffee6	270	25	9.3	24	8.9	3.0	3.6	11.8
Coffee7	200	18	9.0	18	9.0	2.5	2.7	11.7
Coffee8	275	25	9.1	24	8.7	3.0	1.5	10.8
Coffee9	270	24	8.9	21	7.8	1.9	1.5	10.2
Coffee10	200	17	8.5	17	8.5	2.0	1.1	10.2
Coffee11	275	24	8.7	24	8.7	2.0	1.1	10.0
Coffee12	240	21	8.8	18	7.5	1.0	0.7	9.5
Coffee13	200	15	7.5	15	7.5	1.0	1.6	8.9
Coffee14	275	18	6.5	19	6.9	2.2	3.1	8.5
Coffee15	200	13	6.5	13	6.5	1.6	2.2	8.5
Coffee16	200	9	4.5	9	4.5	1.0	0.0	5.1
Coffee17	150	7	4.7	7	4.7	0.0	0.0	4.7
Coffee18	200	9	4.5	8	4.0	0.0	0.0	4.5

	mL	Carbohydrate	A	Sugars	B	Protein	Fat	C
Coffee19	275	12	4.4	11	4.0	0.0	0.0	4.4
Coffee20	200	2	1.0	0	0.0	0.0	0.0	1.1
Coffee21	275	2	0.7	0	0.0	0.0	0.0	0.8
Coffee22	275	2	0.7	0	0.0	1.0	0.0	1.2
Coffee23	200	1	0.5	0	0.0	0.0	0.0	0.5
Coffee24	270	1	0.4	0	0.0	1.0	0.0	0.8
Coffee25	281	32	11.4	30	10.7	5.0	3.2	14.4
Coffee26	281	32	11.4	31	11.0	4.0	3.4	14.1
Coffee27	250	23	9.2	23	9.2	4.0	3.1	12.1
Coffee28	250	24	9.6	23	9.2	4.0	2.3	12.2
Coffee29	200	16	8.0	16	8.0	4.0	5.0	12.6
Coffee30	200	18	9.0	18	9.0	3.0	4.6	12.9
Coffee31	200	23	11.5	19	9.5	3.1	4.0	15.1
Coffee32	200	17	8.5	17	8.5	3.0	3.8	12.0
Coffee33	200	21	10.5	19	9.5	4.0	6.0	15.6
Coffee34	200	16	8.0	16	8.0	3.9	3.3	11.7
Coffee35	200	16	8.0	16	8.0	3.9	3.2	11.6
Coffee36	200	16	8.0	16	8.0	3.9	3.2	11.6
Coffee37	200	19	9.5	17	8.5	3.0	4.0	13.1
Coffee38	200	18	9.0	16	8.0	4.0	4.1	13.1
Coffee39	200	20	10.0	18	9.0	4.0	4.6	14.4
Coffee40	200	18	9.0	17	8.5	4.0	5.0	13.6
Coffee41	200	28	14.0	20	10.0	7.0	6.0	20.6
Coffee42	200	20	10.0	18	9.0	3.0	4.2	13.7
Coffee43	200	19	9.5	18	9.0	3.0	3.1	12.6
Coffee44	240	24	10.0	22	9.2	3.5	4.0	13.2
Coffee45	240	21	8.8	19	7.9	3.5	4.0	12.0
Coffee46	240	23	9.6	21	8.8	3.5	4.0	12.8

Table 5: Measured Values of 46 Samples

	PAL-S	PEN-1st	PEN-J
Coffee1	13.90	14.62	14.20
Coffee2	14.68	15.20	14.56
Coffee3	12.50	12.64	12.36
Coffee4	12.78	12.92	12.40
Coffee5	11.90	11.60	11.20
Coffee6	12.20	12.74	12.48
Coffee7	12.50	12.60	11.96
Coffee8	10.20	10.32	10.44
Coffee9	10.80	10.58	10.30
Coffee10	10.52	9.76	9.38
Coffee11	10.50	10.90	10.58
Coffee12	9.82	8.96	8.58
Coffee13	9.80	8.86	8.60
Coffee14	10.00	10.20	10.56
Coffee15	10.46	9.88	9.50
Coffee16	4.88	4.40	3.80
Coffee17	5.60	5.00	4.60
Coffee18	5.30	5.10	4.90
Coffee19	5.18	5.00	4.90
Coffee20	0.68	0.80	0.36
Coffee21	0.68	1.10	1.00
Coffee22	0.50	0.90	0.80
Coffee23	0.90	0.80	0.40
Coffee24	1.26	1.10	0.98
Coffee25	15.06	16.08	16.00
Coffee26	15.12	16.36	16.00
Coffee27	12.30	12.78	12.48
Coffee28	12.40	12.88	12.72
Coffee29	12.68	13.20	13.12
Coffee30	13.24	14.50	13.76
Coffee31	14.26	15.10	14.90
Coffee32	13.38	13.34	12.98
Coffee33	14.64	19.46	17.00
Coffee34	13.00	13.76	13.44
Coffee35	12.92	13.80	13.10
Coffee36	12.88	13.54	13.20
Coffee37	12.84	13.66	13.48
Coffee38	12.78	12.90	12.62
Coffee39	13.06	13.86	13.24
Coffee40	12.90	13.80	13.54
Coffee41	18.76	22.56	20.20
Coffee42	13.00	13.18	12.70
Coffee43	11.84	12.30	11.94
Coffee44	12.50	13.84	13.30
Coffee45	11.90	12.44	12.14
Coffee46	11.90	12.42	12.16

B. Making calibration curve

The purpose of this study was to draw the calibration curve for refractometer equipment to predict the sugar content of coffee drink which did not clearly suggest in beverages. Most of the commercial drink available in market was suggested sugar content abiding by the guideline of government, but some commercial drinks that is on sale in coffee shop or handmade products do not suggest sugar content [23].

<Table 4> showed the main ingredient of sample A and <Table 5> showed the measured values of total samples. Types of coffee are classified into black, café latte, café mocha, café au lait, caramel macchiato, americano, espresso, etc.

PAL-S refractometer

As shown in [Figure 1], when we set the X-axis as the expected value of sugar content obtained by recalculating the sugars, the measured value went against with the expected value in the range of low concentration of sugars (>1g/100mL). At this point, Y-intercept was 0.49673 which did not pass the zero point and the slope was as high as 1.37218. Therefore, setting the X-axis with the sugar content did not accurately reflect the measured values.

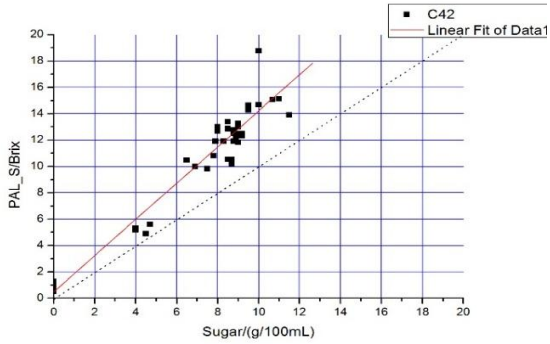

Figure 1. Correlation graph between measured values obtained by using PAL-S refractometer and expected values converted by total sugars content.

Table 6: Linearity of measured value obtained in figure 1

	Value	Error	
A	0.49673	0.47953	
B	1.37218	0.0599	
R	SD	N	P
0.96054	1.22554	46	<0.0001

Next, we investigated the relationship between the measured values and the expected values obtained by converting the total carbohydrate labeled on product. As shown in [Figure 2], the slope showed slight decrease to 1.30315 and the Y-intercept (0.23525) was close to zero point. However, in this case, when sample has higher total of carbohydrate (>4g/100mL), the tendency of less conformity between expected value and measured value was clearer. This result also indicated that setting the total carbohydrate as X-axis did not accurately reflect the measured value.

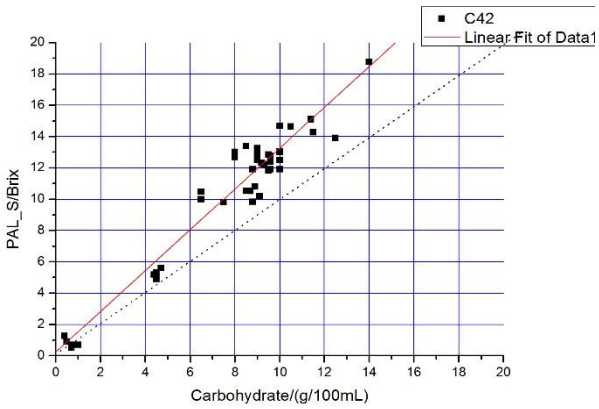

Figure 2. Correlation graph between measured value obtained by using PAL-S refractometer and expected values converted by total carbohydrates content.

Table 7: Linearity of measured value obtained in figure 2

	Value	Error	
A	0.23525	0.47223	
B	1.30315	0.05479	
R	SD	N	P
0.96324	1.18367	46	<0.0001

Next, the X-axis was set as the converted expected value of total carbohydrate, protein, fat and others. As shown in [Figure 3], the expected values and measured values showed a conformity (Y=BX+A, B=0.94954 and A=0.70162). Even in high concentration, it did not deviate from the linear relation and it showed a conformity. This result verified that sugar content measured in PAL-S refractometer showed the total solid concentration dissolved in drink.

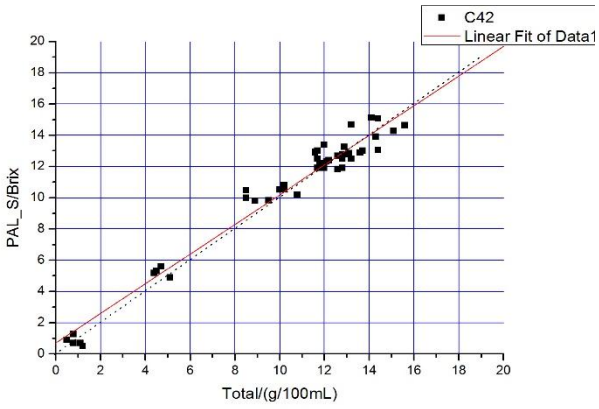

Figure 3. Correlation graph between measured value obtained by using PAL-S refractometer and expected values converted by total dissolved solids content.

Table 8: Linearity of measured value obtained in figure 3

	Value	Error	
A	0.70162	0.30792	
B	0.94954	0.02699	
R	SD	N	P
0.98268	0.81644	46	<0.0001

PEN-1st refractometer

As shown in [Figure 4], when we set the X-axis as the expected values obtained by recalculating only the sugar content, the measured value obtained went against with the expected value in the range of high concentration of sugars. In particular, this difference appeared in more than 1g/100 mL of sugar content in coffee drinks. At this point, the Y-intercept was 0.11697 which passed the zero point and the slope was as high as 1.48449. Therefore, setting the X-axis with the sugar content did not accurately reflect the measured value.

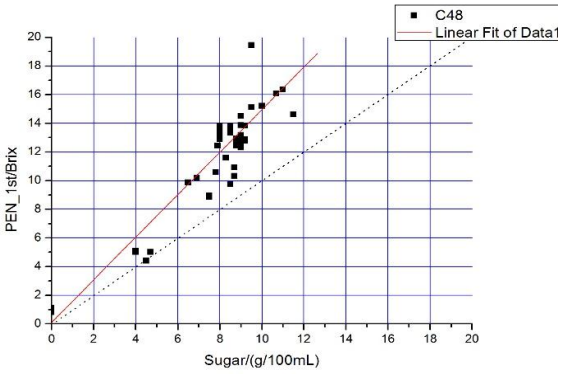

Figure 4. Correlation graph between measured value by using PEN-1st refractometer and expected values converted by total sugars content.

Table 9: Linearity of measured value obtained in figure 4

	Value	Error	
A	0.11697	0.75139	
B	1.48449	0.09386	
R	SD	N	P
0.92218	1.92034	46	<0.0001

As shown in [Figure 5], when we set X-axis as expected value of sugar by converting the carbohydrate content labeled on the drinks, the showed slight decrease to 1.43596 and the Y-intercept was close to zero point which was -0.37535. In the range of low concentration, it showed a high degree of match between the expected values and measured values. But, like as the previous case, in the range of high concentration of sugar in sample was less correlated. If sample is higher total of carbohydrate, the tendency of less conformity between expected values and measured values was clearer. This result indicated that setting the total carbohydrate as X-axis did not accurately reflect the measured value.

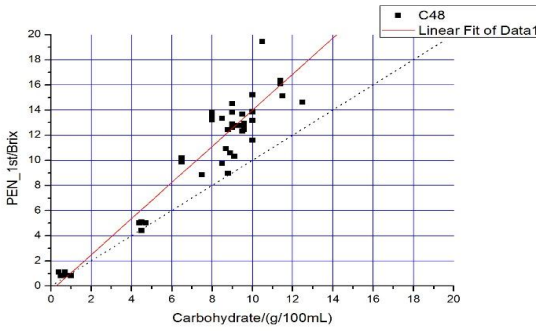

Figure 5. Correlation graph between measured value obtained by using PEN-1st refractometer and expected values converted by total carbohydrates content.

Table 10: Linearity of measured value obtained in figure 5

	Value	Error	
A	-0.37535	0.66522	
B	1.43596	0.07718	
R	SD	N	P
0.94192	1.66741	46	<0.0001

Next, the X-axis was set as the converted expected value of total carbohydrate, protein, fat and other solid to examine the correlation with measured value. As shown in [Figure 6], when we set the X-axis as total solid content, the expected value and measured value showed a good conformity. (Y=Bx+A, B=1.06926 and A=-0.10242). Even in high concentration of sugar, it did not deviate from the linear relation but showed the conformity. This result verified that sugar content measured in PAL-1st refractometer showed the concentration of total dissolved solid in drink. Also, calibration curve to concentration also passed the zero point, so it was verified that PEN-1st refractometer was appropriate for measuring the sugar content in lower concentration.

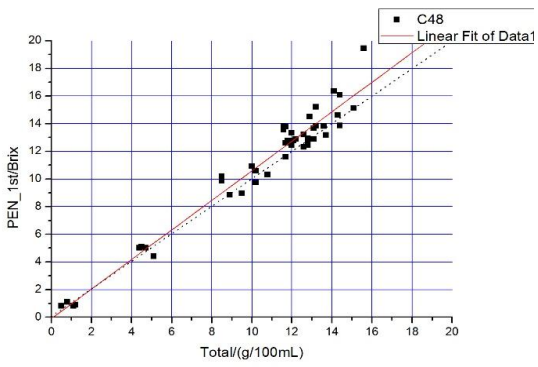

Figure 6. Correlation graph between measured value obtained by using PEN-1st refractometer and expected values converted by total dissolved solids content.

Table 11: Linearity of measured value obtained in figure 6

	Value	Error	
A	-0.10242	0.35357	
B	1.06926	0.03099	
R	SD	N	P
0.98201	0.93747	46	<0.0001

PEN-J refractometer

As shown in [Figure 7], when we set the X-axis as the value of sugar content, the measured value obtained by sample in high-sugar content concentration went against with the expected value. At this point, the Y-intercept was -0.02262 which passed the zero point and the slope was as high as 1.44796. Therefore, setting the X-axis only with the sugar content did not accurately reflect the measured value.

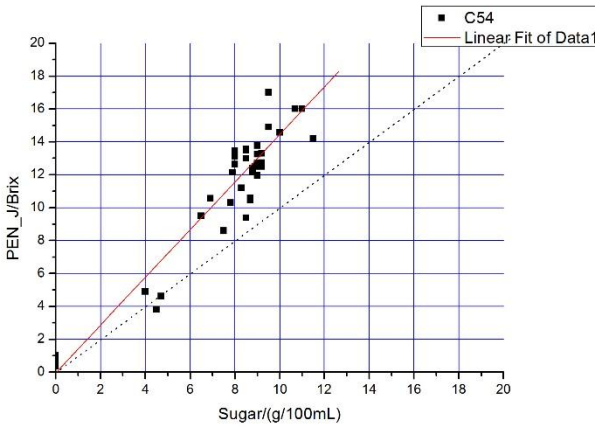

Figure 7. Correlation graph between measured value obtained by using PEN-J and expected values converted by total sugars content.

Table 12: Linearity of measured value obtained in figure 7

	Value	Error	
A	-0.02262	0.63971	
B	1.44796	0.07991	
R	SD	N	P
0.93905	1.63492	46	<0.0001

Next, the relation between the expected value converting the total carbohydrate labeled on product and measured value was examined. As shown in [Figure 8], when we set X-axis as carbohydrates content, the slope showed slight reverse decrease to 1.38638 and Y-intercept was close to zero point which was -0.38874. However, the tendency of less conformity between expected value and measured value was clearer in the range of high concentration. This result indicated that setting the total carbohydrate as X-axis did not accurately reflect the measured value.

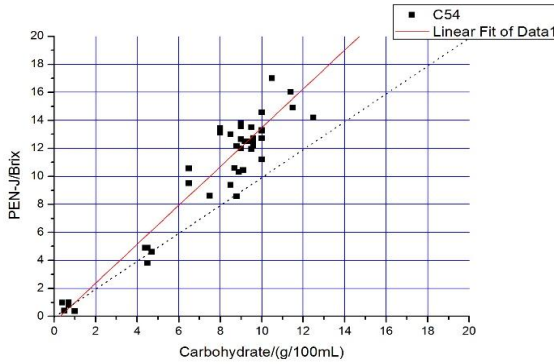

Figure 8. Correlation graph between measured value obtained by using PEN-J refractometer and expected values converted by total carbohydrates content.

Table 13: Linearity of measured value obtained in figure 8

	Value	Error	
A	-0.38874	0.59586	
B	1.38638	0.06913	
R	SD	N	P
0.94941	1.49356	46	<0.0001

Next, the X-axis was set as the converted expected value of total carbohydrate, protein, fat and other solid to examine the correlation with measured value. As shown in [Figure 9], when we set total solid as the standard, the expected value and measured value showed a good conformity. (Y=BX+A, B=1.02571 and A=-0.05561). Even in high concentration of sugar, it did not deviate from the linear relation but showed the conformity. This result verified that sugar content measured in PEN-J showed total dissolved solid (TSD) in drink. Also, the calibration curve also passed the zero point, it was verified that PEN-J refractometer was appropriate for measuring the sugar content in lower concentration.

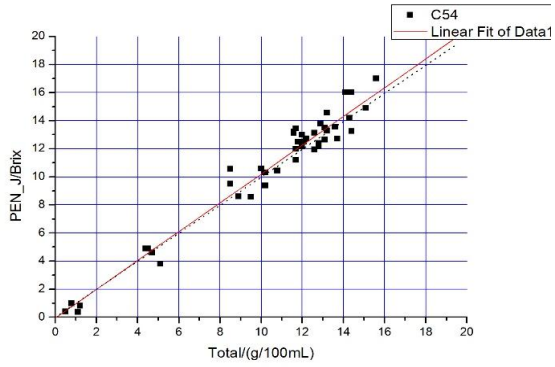

Figure 9. Correlation graph between measured value obtained by using PEN-J refractometer and expected values converted by total dissolved solids content.

Table 14: Linearity of measured value obtained in figure 9

	Value	Error	
A	-0.05561	0.32491	
B	1.02571	0.02848	
R	SD	N	P
0.98346	0.86149	46	<0.0001

C. Calculation of sugar content with unknown sample

From these results, we could be made the calibration curve for each measurement apparatuses. As for the unknown concentration of coffee bought in the market and coffee shop, the calibration obtained by this study was utilized to obtain the value of sugar content.

We firstly detected the sugar content (I) with sample X by three refractometers. With the same experiment method, the result obtained by three measurement equipment was as <Table 15>. The concentration of sugar (II) in sample X was attained by adapting the calibration(Y=BX+A) of each measurement equipment based on the result. And obtained value (III) was converted into the standard amount (100mL) and identified it.

Table 15: Sugar content for unknown concentration of samples (value of I) means an experimental value, (value of II) means a recalculated value by using the calibration curve, (value of III) means the confirmed the value by recalculated the volume

		PAL-S			PEN-1st			PEN-J		
Sample	mL	**I**	**II**	**III**	**I**	**II**	**III**	**I**	**II**	**III**
Coffee1	175	9.86	9.65	5.51	9.04	8.55	4.89	8.72	8.56	4.89
Coffee2	200	10.30	10.11	5.05	9.70	9.17	4.58	9.32	9.14	5.22
Coffee3	200	9.98	9.77	4.89	9.18	8.68	4.34	8.90	8.73	4.99
Coffee4	240	10.92	10.76	4.48	10.60	10.01	4.17	10.00	9.80	5.60
Coffee5	200	10.66	10.49	5.24	10.10	9.54	4.77	9.80	9.61	5.49
Coffee6	100	11.66	11.54	11.54	11.50	10.85	10.85	10.98	10.76	6.15
Coffee7	100	11.88	11.77	11.77	11.50	10.85	10.85	11.20	10.97	6.27
Coffee8	240	9.68	9.46	3.94	8.70	8.23	3.43	8.40	8.24	4.71
Coffee9	175	10.38	10.19	5.10	10.32	9.75	4.87	10.16	9.96	5.69
Coffee10	200	5.30	4.84	2.02	5.10	4.87	2.03	4.90	4.83	2.76
Coffee11	300	10.08	9.88	3.29	10.08	9.52	3.17	10.30	10.10	3.37
Coffee12	170	9.80	9.58	5.64	9.50	8.98	5.28	9.50	9.32	5.48

CONCLUSIONS

In this study, we performed the measurement of investigated the sugar content in Korean coffee drinks by using three different kinds of refractometer including pen-typed.
From this result, we found that the portable refractometers were usable to detect the content of sugar in Korean coffee drinks. And we confirmed that the measured values obtained by three different kinds of refractometers showed not only sugar content and carbohydrate but also the total dissolved solids contained in drink.
And, we could be predicted the concentration of sugar(TDS) in unlabeled coffee drinks by using the calibration curves obtained from this study. However, there is a need for much detailed analysis to get the exact calibration curves in future.

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